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REPORT

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DESIGN DATA BROCHURE FOR THE OWENS-ILLINOIS SUNPAK™  
AIR-COOLED SOLAR COLLECTOR

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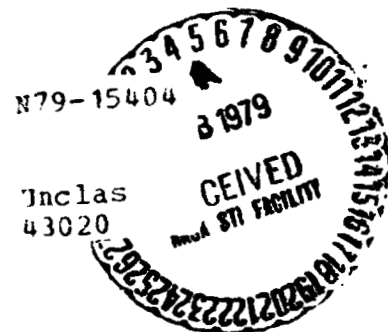
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16. ABSTRACT  This report contains the information necessary to evaluate the design and installation of the Owens-Illinois Sunpak <sup>TM</sup> Air-Cooled Solar Collector. Information includes collector features, fluid flow, thermal performance, installation and system tips.  This document has been slightly modified in the interest of clarity.					
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### **The Owens-Illinois Sunpak™ Air-Cooled Collector**

Owens-Illinois Sunpak™ Group has added an air-cooled collector to its advanced solar thermal collector family. The collector utilizes a highly selective wavelength coating in combination with vacuum insulation, which virtually eliminates conduction and convection losses. Sunpak is a high performance, high temperature, air-cooled collector available for commercial applications.

The Model SEC-601 air-cooled collector extends the versatility of the Sunpak family. The Model SEC-601 collector combines the many advantages of using air as the heat transfer fluid with the high thermal performance of selectively coated low loss evacuated tubular collector elements. Qualified and certified under NASA Contract No. NAS8-32259, the Model SEC-601 collector has completed the rigorous test procedures of the Interim Performance Criteria (IPC) for Solar Heating and Combined Heating/Cooling Systems and Dwellings dated January 1, 1975.

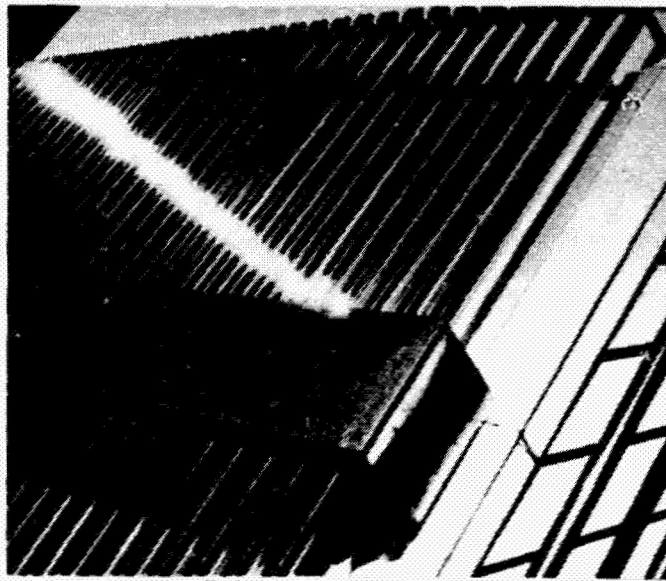


Figure 1 Sunpak™ Model SEC-601 Air-Cooled Collector Module

#### **Features**

- .Qualified and certified to the IPC for heating and cooling systems and dwellings.
- .Thermal performance certified by an independent agency.
- .Safety - Problems of freezing, boiling and secondary damage due to liquid leaks eliminated.
- .Reliability - No filling or draining problems.
- .Light weight - Ease of new or retrofit installation.
- .Structural integrity - Qualified by test to withstand 150 mph wind loads, thermal and mechanical cyclic loads, earthquake, snow and ice loads. Withstands up to 1.25 inch diameter hail at terminal velocity.

.Tube element breakage does not disrupt collector operation.

.Leak tight to less than 1% design flow; system heat loss and air pumping power are minimal.

.Safe to long-term exposure at high temperature stagnation (no fluid flow) conditions. No thermal shock failure.

.Corrosion-erosion problems eliminated. (No fluid additives or fluid treatment required. Pollution problems from the disposal of waste fluids eliminated. No cost air is used.)

.High performance-high thermal efficiency operation.

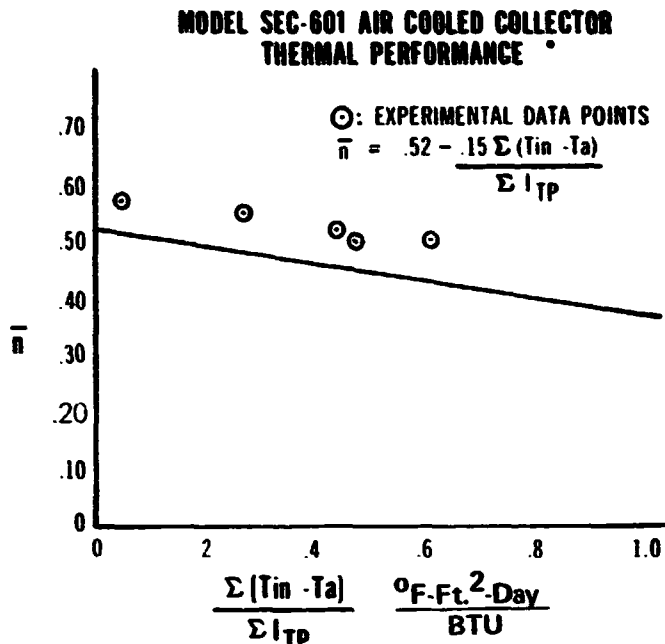
.Simple single wall heat exchange for domestic hot water heating applications.

.Modular in design for minimum on site labor and installation cost.

Modular in construction, a 72 tube unit may be ground assembled, lifted to position and installed with a minimum of on site labor. Weighing less than 340 pounds with tube elements installed (120 pounds without the tube elements), the 100 square foot unit is easy to handle. Since the roof is used as the diffuse reflecting backing screen, virtually no additional loading of the structure results even under high wind conditions. The tubular elements are about eight inches above the roof line and shed snow easily. Collector performance testing during the heavy snow conditions of the 1978 Toledo winter demonstrated virtually no lost days due to snow cover.

Since the same basic tubular elements are used for either air or liquid cooled collectors, the long development and service experience of the Sunpak collector is applicable. The optical characteristics, the demonstrated strength and service life of the KG-33 borosilicate glass, the vacuum protected selective coating and the low coefficient of thermal expansion and attendant high thermal shock resistance are unique features of the Sunpak collector family. The liquid cooled member, in field demonstration projects since 1975, has accrued the field service experience yielded only by thousands of installed square feet evaluated under actual operating conditions delivering high quality energy to a variety of load applications. The largest single liquid cooled collector installation is the 7000 square foot array used to drive conventional cooling equipment for the Government Services Administration (GSA) Building, Saginaw, Michigan. Successful operation during the cooling season of 1977 and the heating season of 1978 has demonstrated the year-round performance capability of the Sunpak liquid cooled evacuated tubular collector.

## Thermal Performance



\*NOTE: All equations and graphs are based on effective installed area which is equal to 80% of total installed area for this collector.

Figure 2 Thermal Performance

Thermal performance is presented on an all day operating basis rather than the solar noon instantaneous efficiency condition. The data points represented by circles were obtained for relatively clear day conditions. The collector was south facing at a tilt of 45° in Toledo, Ohio, at a latitude of 41°. The test period was from April 12 to May 20, 1978. The test procedures, instrumentation and data reduction were conducted under the surveillance of an independent agency, Smith, Hinchman and Grylls, Detroit, Michigan. Each point represents one full day of testing. Thus, optical effects due to the angle of incidence of solar radiation and the physical characteristics of the collector such as its thermal mass and time constant are integrated over an operating day. The reported performance is penalized for any time during the day when the operating conditions resulted in a negative gain; the energy lost was subtracted from the energy gained to arrive at the net gain for the day.

To a good engineering approximation, a reasonable first cut at predicted performance may be obtained by using monthly daily averages of insolation transformed to the tilt plane of the collector and average daily ambient temperatures. Wind speed and relative humidity have virtually no impact on thermal performance. The only assumption required is the value of the collector inlet fluid temperature summed over the operating day.

The insensitivity of the performance predictions to an error in assumption for  $\sum T_{in}$  is a unique feature of a very low loss characteristic collector. While a "smart" controller would allow collector fluid flow only under conditions of useful energy gain, the use average daily sunshine hours results in only a minimal penalty (conservative estimate) due to the low threshold level of insolation required by the collector. To predict the thermal performance of the collector:

#### Procedure

**Step 1** Determine the long-term monthly daily average for the solar insolation at the selected geographic location from the Climatic Atlas or other accepted source.

Example: Madison, Wisconsin

June	December
$\bar{H} = 1895 \frac{\text{BTU}}{\text{Ft.}^2 \cdot \text{Day}}$	$\bar{H} = 424 \frac{\text{BTU}}{\text{Ft.}^2 \cdot \text{Day}}$

**Step 2** Transform the daily average insolation from the reference plane to the tilt plane of the collector

Example: Madison, Wisconsin

(Collector Tilt = 53°)

$\sum I_{Tp} = 1463 \frac{\text{BTU}}{\text{Ft.}^2 \cdot \text{Day}}$	$\sum I_{Tp} = 877 \frac{\text{BTU}}{\text{Ft.}^2 \cdot \text{Day}}$
---	--

**Step 3** Select the average fluid inlet temperature for the intended operating condition.

Example: Madison, Wisconsin

Hot Water Heating	Space Heating
$T_{in} = 140^\circ\text{F}$	$T_{in} = 80^\circ\text{F}$

**Step 4** Determine the daytime daily average temperature from the reference source.

Example: Madison, Wisconsin

$T_a = 75^\circ\text{F}$	$T_a = 29^\circ\text{F}$
--------------------------	--------------------------

**Step 5** Subtract Step 4 from 3 and multiply by the daily average hours of sunshine for the month taken from selected source.

Example: Madison, Wisconsin

$\sum (T_{in} - T_a) = (140 - 75)9.5$	$\sum (T_{in} - T_a) = (80 - 29)3.5$
= 618	= 179

Step 6 Enter data into the characteristic equation of the collector efficiency curve.

• Example: Madison, Wisconsin

June

December

$$\begin{aligned} n &= .52 - .15(618/1463) \\ n &= .46 \end{aligned}$$

$$\begin{aligned} n &= .52 - .15(179/877) \\ n &= .50 \end{aligned}$$

Step 7 Multiply Step 2 by Step 6 to obtain the predicted useful energy gain of the collector per square foot of effective installed area. (Effective installed area equals 80% of total installed area.)

Example: Madison, Wisconsin

$$q_u = 1463 \times .46$$

$$q_u = 877 \times .50$$

$$q_u = 673 \frac{\text{BTU}}{\text{Ft.}^2\text{-Day}}$$

$$q_u = 439 \frac{\text{BTU}}{\text{Ft.}^2\text{-Day}}$$

Ft.<sup>2</sup>-Day

Ft.<sup>2</sup>-Day

Step 8 Multiply Step 7 by the number of days per month to obtain the useful energy gain of the collector per month.

Example: Madison, Wisconsin

$$q_u = 673 \times 30$$

$$q_u = 439 \times 31$$

$$q_u = 20,190 \frac{\text{BTU}}{\text{Ft.}^2\text{-Month}}$$

$$q_u = 13,609 \frac{\text{BTU}}{\text{Ft.}^2\text{-Month}}$$

The collector area required for the application is determined by the solar system designer based on the load requirements and the percent of total load expected to be provided by solar.

For more accurate results, the daily thermal performance characteristic equation may be used directly in thermal performance predictions through the use of such procedures as the "f" chart<sup>1</sup> approach. It should be noted, however, that the upper temperature limits at which energy must be dumped and the threshold insolation level at which the collector will turn on are much different than the assumptions used in generating the background data from which the "f" chart procedure was developed.

### Fluid Flow

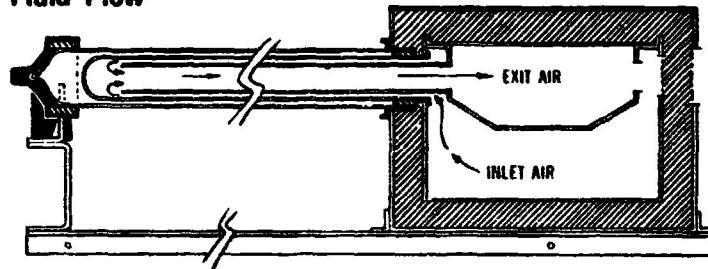


Figure 3 Parallel Air Flow Path

The 72 collector tube elements are mounted in a parallel flow path arrangement. This minimizes the pressure drop due to air flow in the collector which is 0.38 inches of water gage at the design flow rate of 2CFM per tube (144CFM per module). The manifold ducting is sized to minimize the static pressure gradient and is center fed to equalize flow distribution in each of the tubes. The exit or higher temperature air duct is contained essentially within the inlet or lower temperature air duct to minimize duct heat loss. For other than design flow condition, test data demonstrate the empirical relationship between air flow and pressure drop to be:

$$\Delta P = 0.1 (\text{CFM})^{1.92}$$

$$\Delta P = \text{inches, w.g.}$$

$$\text{CFM} = \text{volume flow in Ft.}^3/\text{min per tube}$$

Because of the very low loss coefficient of the collector, relatively low air mass flow rates may be used without a significant degradation in thermal performance. This minimizes the air pumping power requirements. For example, at 2CFM volume flow per tube, the collector pressure drop is only 0.38 inches, w.g. Allowing for pressure drops in ducting and other system components, a total system pressure drop of 0.6 inches, w.g. would be feasible. The air fan pumping power requirement at a 15% fan efficiency for a Model SEC-601 collector module would be:

$$\text{HP} = \frac{157.5 \times 10^{-6}}{\eta_F} \times P \times \text{CFM}; \text{HP}$$

$$\Delta P = \text{inches, w.g.} = 0.6 \text{ in., w.g.}$$

$$\text{CFM} = \text{Total volume flow} = 2 \times 72 = 144 \text{CFM}$$

$$\eta_F = \text{Fan efficiency} = 15\%$$

$$\text{HP} = 0.09 \text{ HP} = 231 \text{BTU/HR}$$

<sup>1</sup> Klein, S.A., Beekman, W.A., Dujfie, J.A. "Design Procedures for Solar Heating Systems"

### Installation

A Sunpak Model SEC-601 air-cooled collector contains 72 collector tube elements. A close-up of a section of a module is shown in Figure 4. The modular design also includes the air manifold and interface ducts, the tube end support brackets, the rail support structure and roof mounting brackets. Without the tube elements in place, the remainder of the 72 tube module weighs only 120 pounds. With the tubes installed, the total weight of the module is less than 340 pounds. Thus, the tubes could be ground installed and the module lifted to the mounting position with a minimum of handling equipment. Deflections of the support structure during handling will not cause damage to the glass tubes or resilient seal elements. The module is pressure tested at the factory for air leakage (1.0% design flow maximum) prior to shipment.

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Figure 4 Close-up of Module Manifold, Collector Tubes Installed and T Bar Support Structure

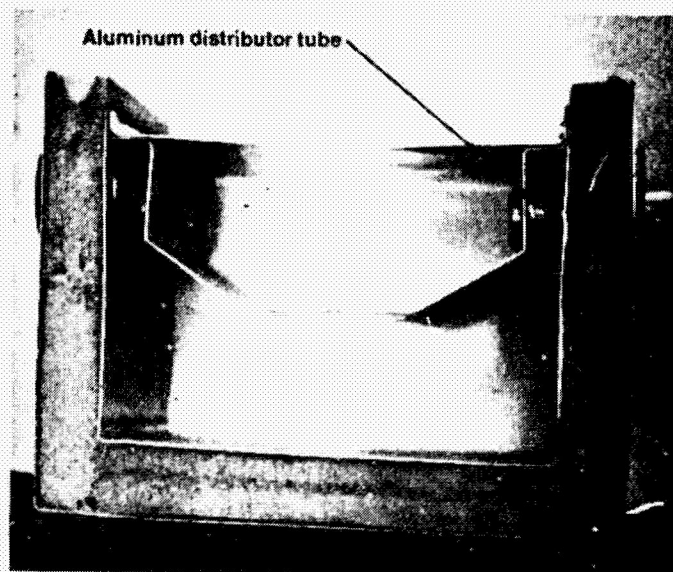


Figure 5 Aluminum Distributor Tube Threaded into Socket in Inner Duct.

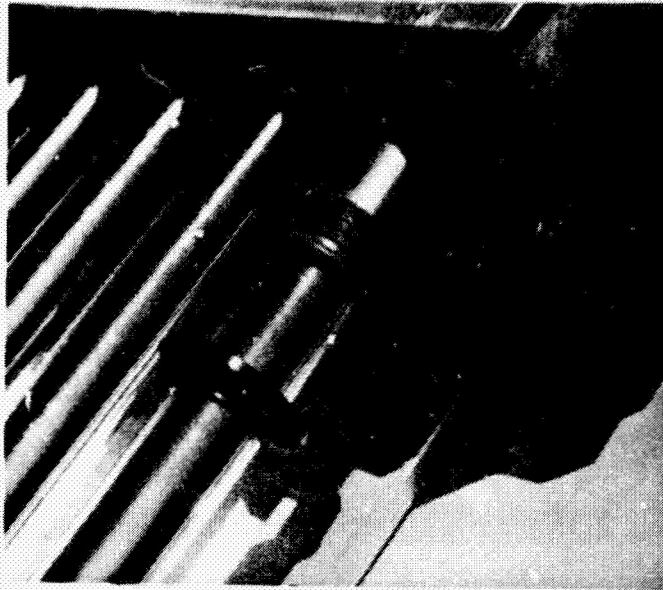


Figure 6 Detail of a Section of the Model SEC-601 Collector

The silicone rubber labrinth air seal and tube cushion is cemented to the cover tube at the factory. The subassembly is pushed into its socket and rotated slightly to insure full insertion. The water retarding cover is tanged and mates with slots in the manifold well socket. A 45° rotation ensures full enngement and protection.

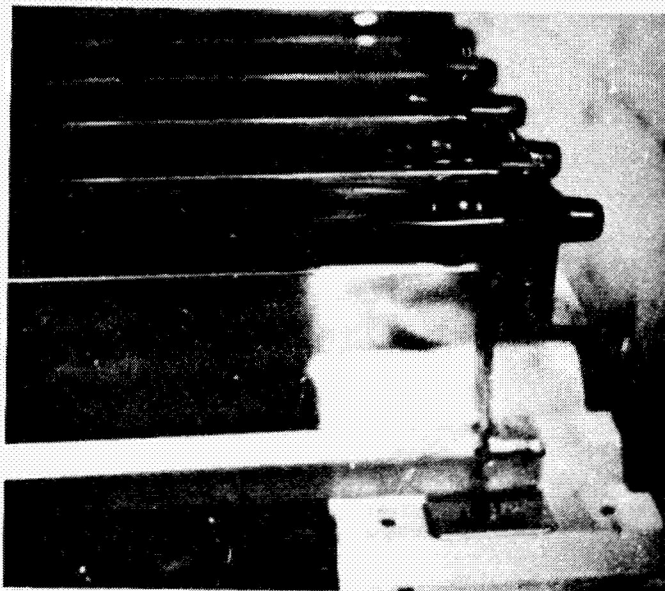
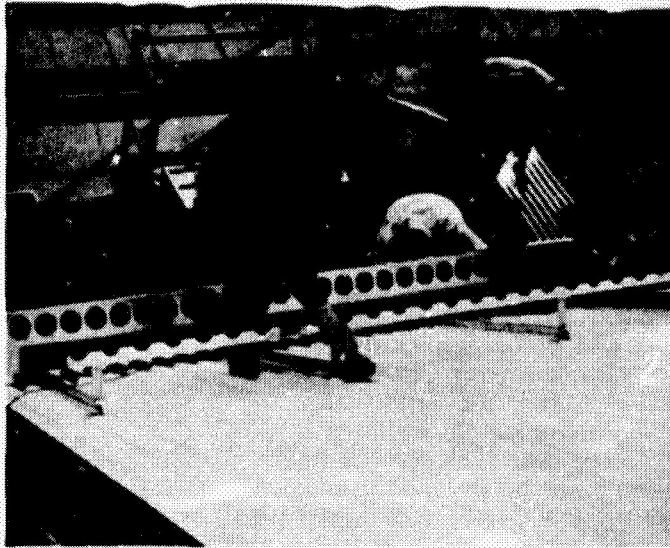


Figure 7 Tube End Support Bracket & Support Cups

To complete the installation, the outboard tube end support cup is snapped into place by exerting a forward and downward rotating force.



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Figure 8 Prepared Roof and Module (less tubes)

The roof area behind the collector module is prepared by installing Alcoa Bone White No. K2028-30 (fluorocarbon) or equivalent, diffuse radiation material. The 4 inch ribbed industrial sheet was used in the IPC Verification Test Program. The roof penetrating air ducts which interface with the manifold air transition ducts are also prepared prior to installing the collector module. The preassembled module support structure, with manifold in place, may be attached to the raised surface of the 4 inch ribbed sheet using Molly type blind hold attachments for each of the 20 mounting pads per module.

#### System Tips

- The high temperature performance of the Model SEC-601 Collector and the absence of storage pressure problems due to operating temperature (using rock bed storage of thermal energy) could result in lower storage size and cost.
- The low loss coefficient of the collector allows the addition of an air liquid heat exchange element without significant loss in thermal performance. Where the liquid medium represents a small percent of the load a low effectiveness ( $\sim 25\%$ ) heat exchange element may be used; where the liquid medium represents a high percentage of the load, a higher effectiveness ( $\sim 50$  to  $60\%$ ) heat exchange element should be used.

- Two thermocouples (copper-constantan Type T) are supplied with each module. They are located in the annulus area of a tube element about mid-way along the axial length of the tube. The indication of air temperature in the tubes may be considered in establishing system control strategy.

The Model SEC-601 air-cooled collector has been qualified for continuous operation for up to 325°F exit air temperatures. This limit is related to potential long term degradation of the insulation and an attendant increase in heat loss. Operating instructions require that collector start-up be limited to a measured stagnation temperature within the collector of 450°F or less. This limit is not related to thermal shock or any catastrophic failure mode: repeated exposure to excessive high temperature start-up or continued operating temperatures above 350°F could cause a gradual loss in thermal performance due to an induced increase in air leakage or to the degradation of the insulating properties of the system. The collector can withstand long-term exposure to high temperature stagnation (no air flow) conditions without degrading the operating thermal performance characteristics.

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